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(54) Error correction of digital signals

(57) Data receiving apparatus for receiving an input digital signal (e.g. a digital audio or video signal from magnetic tape 20) having an input signal data stream and associated error correction data, comprises an error detector for detecting a quantity of data errors in the input signal data stream; an error corrector 30 for correcting data errors in the input signal data stream using the associated error correction data, to generate an error-corrector-processed signal data stream; and signal degrading means 40 for degrading a signal derived from the error-corrector-processed signal data stream by an amount dependent on the detected quantity of data errors in the input signal data stream. The signal degrading means can provide an output signal (e.g. a separate monitoring signal) in which the apparent degree of signal degradation (e.g. visual noise in the case of a video signal) increases as the uncorrected bit error rate increases. This gives an indication to the user that the error rate in the uncorrected data is increasing, even if the error correction system can still provide 100% correction.

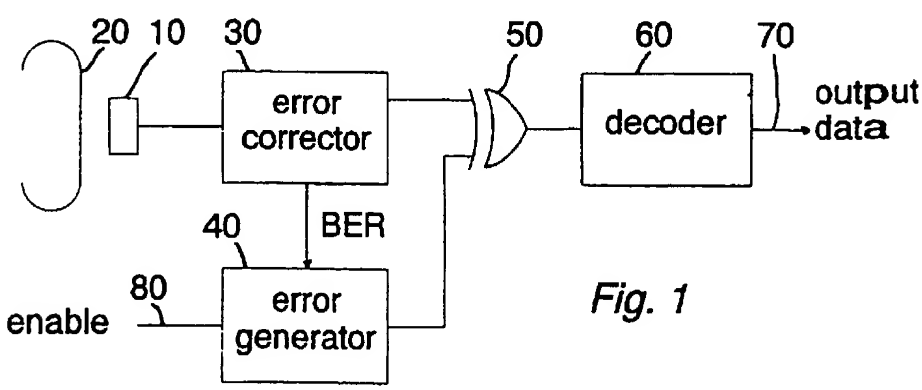

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

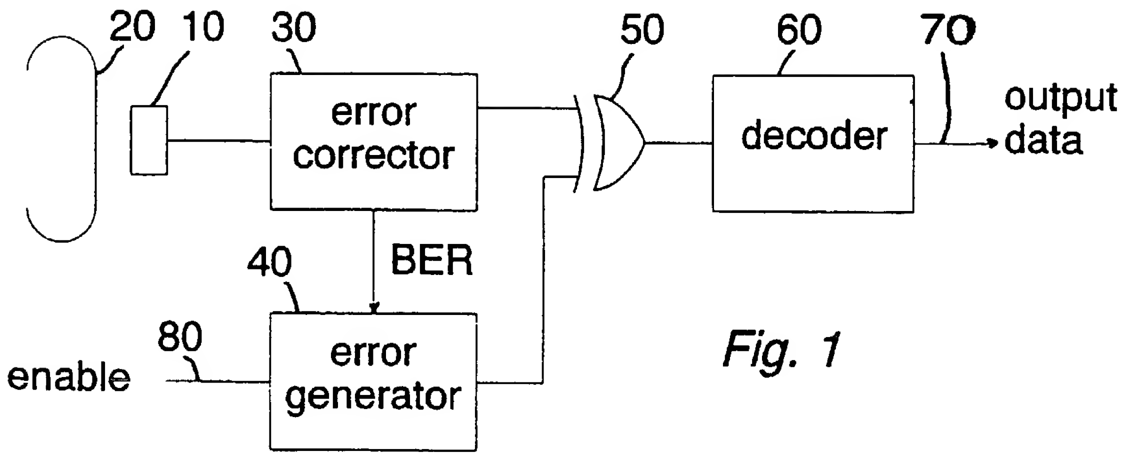

Fig. 1

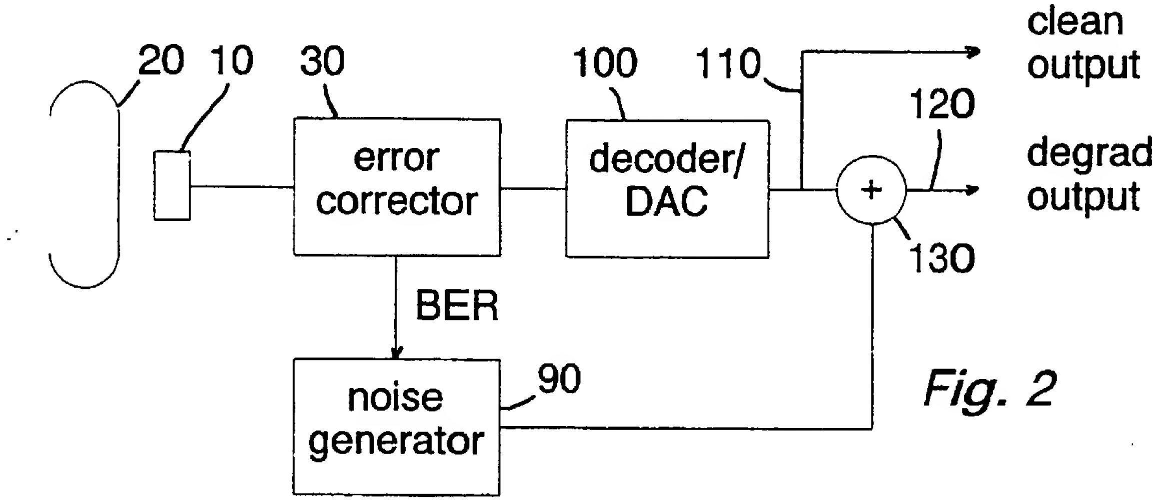

Fig. 2

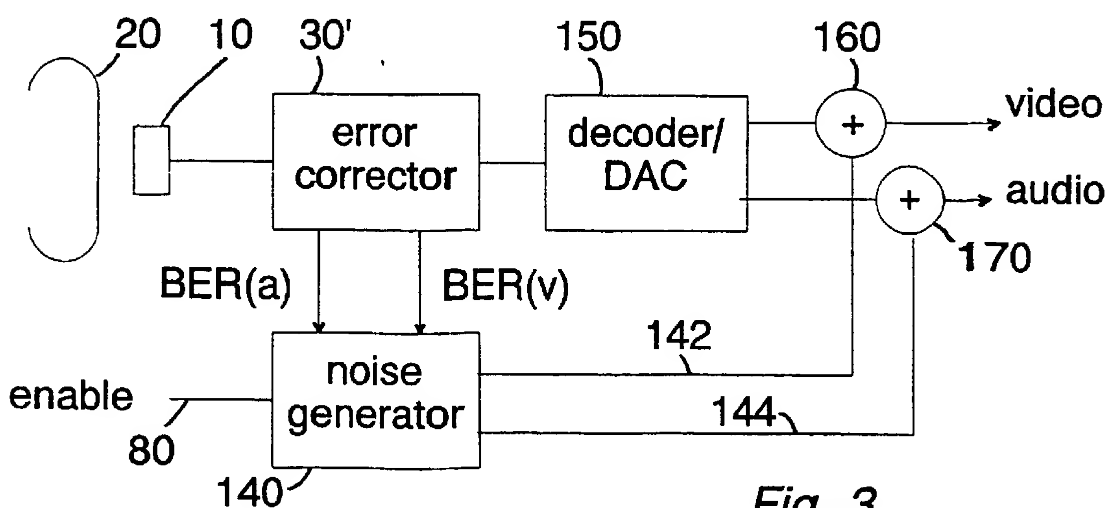

Fig. 3

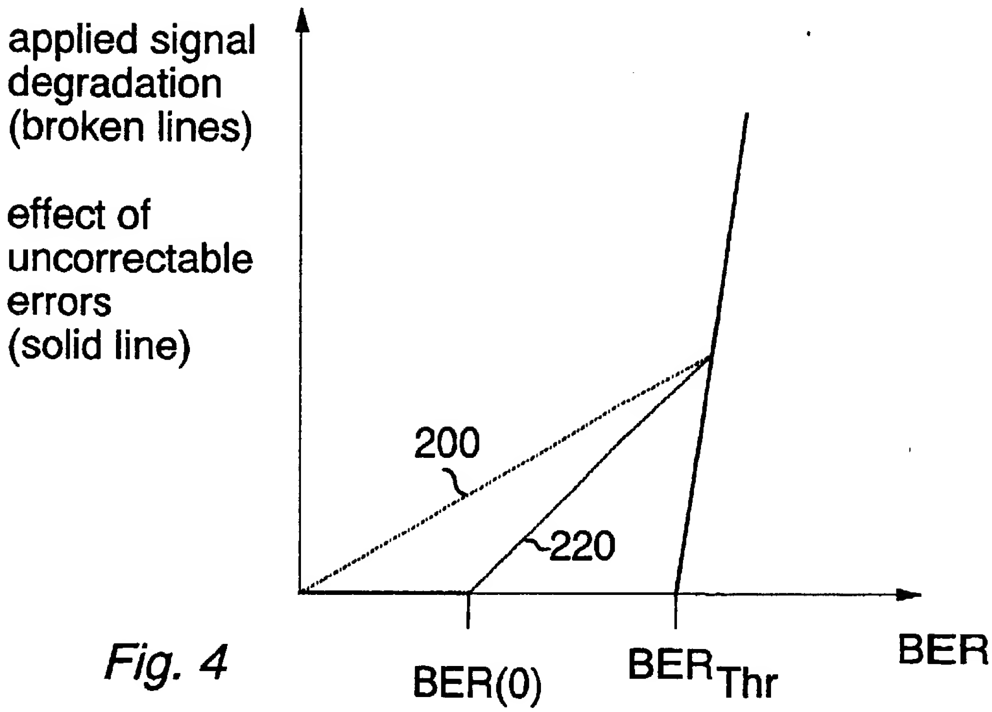
applied signal
degradation
(broken lines)
effect of
uncorrectable
errors
(solid line)
200
220
BER(0)
BER_{Thr}
BER

Fig. 4

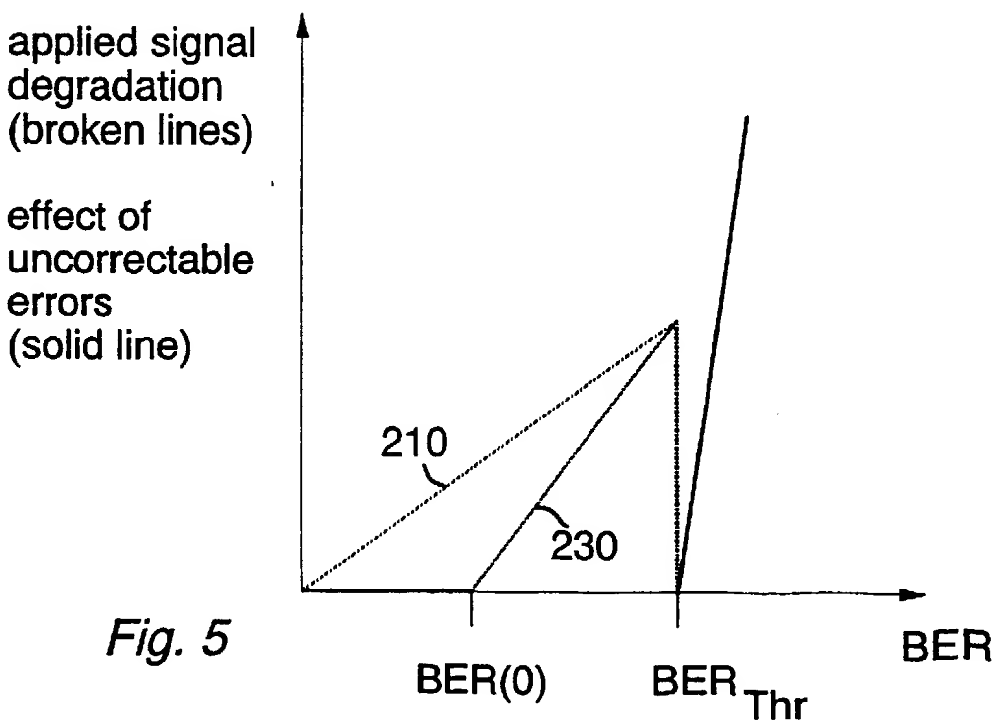
applied signal
degradation
(broken lines)
effect of
uncorrectable
errors
(solid line)
210
230
BER(0)
BER_{Thr}
BER

Fig. 5

ERROR CORRECTION OF DIGITAL SIGNALS

This invention relates to error correction of digital signals.

When digital data, such as data representing an audio or video signal, is recorded or transmitted over a data channel exhibiting noise or distortion, the data can become corrupted by data errors. These data errors may be in the form of individual incorrect data bits or longer bursts of bit errors, and the errors can lead to subjectively disturbing noise in the reconstructed audio or video signal.

This problem of data corruption through noise or distortion is present for practically any real data channel. In order to overcome the problem, systems of error detection and error correction have been proposed. Systems of this type are well documented and generally involve adding extra error correction data to the original encoded data stream before the data is transmitted or recorded. On replay or reception, the extra error correction data can be used to correct data errors of up to a certain level of severity.

The severity of data errors which can be fully corrected by an error correcting code depends on the coding technique used and also on the quantity of extra error correcting data which is provided. For data errors below this level of severity, 100% correction can be achieved. Above this level of severity, the data errors will not be fully corrected and will therefore be evident in the reconstructed audio or video signal.

A digital data channel with error correction therefore introduces an error *threshold*, so that data errors below the threshold rate go entirely unnoticed by the user because they can be 100% corrected, whereas a small increase in the error rate to slightly above the threshold error rate can lead to a catastrophic collapse of the error correction system and dramatic effects on the reconstructed audio or video signal. A problem then arises because user generally has no way of knowing just how close the system is to that error rate threshold.

This invention provides a data receiving apparatus for receiving an input digital signal comprising an input signal data stream and associated error correction data, the apparatus comprising:

an error detector for detecting a quantity of data errors in the input signal data stream;

an error corrector for correcting data errors in the input signal data stream using the associated error correction data, to generate an error–corrector–processed signal data stream; and

signal degrading means for degrading a signal derived from the error–corrector–processed signal data stream by an amount dependent on the detected quantity of data errors in the input signal data stream.

The invention provides a technique for progressively and deliberately degrading a signal derived from the output of the error corrector (even though that output might have been 100% corrected) to indicate the quantity of errors in the input signal data stream before error correction.

By this counter–intuitive step of deliberately applying degradation to the signal, the user can be made aware of the presence of errors in the input signal data stream in a progressive manner, preferably mimicking the way in which noise and distortion become progressively more noticeable in a signal transmitted or recorded using analogue techniques.

When the user becomes aware by this technique that the error rate before correction is increasing, he can take steps to avoid exceeding the correction capabilities of the error corrector. For example, if the input signal data stream is replayed from a magnetic tape, the user could make a fresh copy of the (corrected) data stream onto another tape. If this is done before the correction capabilities of the error corrector are exceeded, the fresh copy can be an error free version of the data stream. Alternatively, if the input signal data stream is received via, for example, a satellite link, the user can investigate why the link is causing large numbers of errors in the received data.

The degrading operation could be performed continuously, but it is preferred that the operation of signal degrading means is switchable on and off by the user or that the signal degrading means applies the signal degradation to a parallel but separate output signal (thus retaining a non–degraded output of the apparatus).

Although it might be argued that one way of demonstrating the error rate before correction would be to switch off the error correction altogether, the invention provides a much more advantageous solution. Using embodiments of the invention, the signal degradation can be controlled – for example to be applied substantially

evenly throughout the degraded signal (e.g. evenly across a video picture represented by the degraded signal) or to be applied always to a particular portion of the degraded signal (e.g. a small section of a video picture represented by the degraded signal). In contrast, simply switching off the error correction would lead to errors appearing at random positions and with different subjective effects in the output signal.

In one embodiment the signal degradation can be added digitally, for example by adding data errors to the error-corrector-processed signal data stream. In another embodiment having a digital to analogue converter for converting data derived from the error-corrector-processed signal data stream into an analogue output signal, the signal degradation can be added as an analogue noise signal to the analogue output signal.

Although the signal degrading means could apply signal degradation according to a number of functions, for example in direct proportion to the quantity of detected errors, it is preferred that the signal degrading means is operable:

(i) not to apply any signal degradation when the detected quantity of errors in the input signal data stream is below a first threshold value; and

(ii) for a detected quantity of errors in the input signal data stream greater than the first threshold value but less than a second threshold value, to apply an amount of signal degradation substantially in proportion to the detected quantity of errors minus the first threshold value. Thus, if the quantity of detected errors is below the first threshold value, and so may be well within the correction capabilities of the error corrector, there is no need to draw the user's attention to such a low error rate.

Preferably the second threshold value corresponds to the smallest quantity of errors at which the error corrector is incapable of fully correcting using the associated error correction data. It is then preferred that the signal degrading means is operable:

(iii) not to apply any signal degradation when the detected quantity of errors in the input signal data stream is above the second threshold value. In other words, once the error corrector can no longer provide full correction, the real (uncorrected) errors will be seen by the user and thus there is no longer a need for the artificial signal degradation introduced by the degrading means.

These techniques are particularly applicable to digital representations of analogue quantities, such as digital video or audio data.

The apparatus is particularly useful in digital recording/reproducing apparatus.

Viewed from a second aspect this invention provides a method of processing an input digital signal comprising an input signal data stream and associated error correction data, the method comprising the steps of:

detecting a quantity of data errors in the input signal data stream;

correcting data errors in the input signal data stream using the associated error correction data, to generate an error-corrector-processed signal data stream; and

degrading a signal derived from the error-corrector-processed signal data stream by an amount dependent on the detected quantity of data errors in the input signal data stream.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figures 1, 2 and 3 are schematic diagrams of digital video reproducing apparatus;

Figures 4 and 5 are schematic graphs illustrating amounts of signal degradation against increasing bit error rate.

Figure 1 is a schematic diagram of a digital video reproducing apparatus.

A digital video signal is read by a magnetic head 10 from a magnetic tape 20. The replayed digital video signal, comprising a signal data stream and associated error correction data, is supplied to an error corrector 30 which operates using known error correction techniques to correct data errors in the signal data.

As part of the operation of the error corrector, a "BER" (bit error rate) signal is generated indicating the current bit error rate of the replayed signal data (i.e. before error correction).

The BER signal is supplied to an error generator 40 which generates data errors to be combined with the error corrector-processed signal output by the error corrector 30 in an exclusive-OR gate 50. The output of the exclusive-OR gate 50 is supplied (optionally) to further decoding circuitry 60 before being output as output video data 70.

The error generator 40 generates data errors for insertion into the error-corrector-processed data in dependence on the BER value provided by the error

corrector 30. The relationship between the quantity of errors generated by the error generator 40 and the BER value will be described below with reference to Figures 4 and 5. Briefly, however, the error generator 40 generates larger numbers of errors for insertion into the error–corrector–processed data as the BER value increases. Thus, even though the error corrector 30 may be operating at an error level which can be 100% error corrected, the output video data 70 is deliberately degraded by the insertion of errors from the error generator 40 to give an indication to the user of the "raw" (off–tape) error rate.

The error generator 40 is controlled by an "enable" signal 80, so that the signal degrading operation of the error generator 40 can be switched on and off by the user.

In this embodiment, the errors generated by the error generator 40 are inserted into the error–corrector–processed data by the exclusive–OR gate 50. When an error output 45 of the error generator 40 is a logical 1, this has the effect of inverting the data supplied to the other input of the exclusive–OR gate 50. When the error output signal 45 is a logical 0, the data at the other input of the exclusive–OR 50 is unchanged.

Clearly, however, this is merely one example of how the errors could be applied to the digital data output by the error corrector 30, and many other similar logic circuits could be envisaged by the skilled man to insert data errors digitally into the error–corrector–processed data stream.

Figure 2 is a schematic diagram of a second embodiment of a digital video reproducing apparatus. In Figure 2, the magnetic head 10, magnetic tape 20 and error corrector 30 are identical to those described above with reference to Figure 1.

In Figure 2, however, a signal degradation is generated by an analogue noise generator 90, which generates an analogue noise signal (e.g. a white noise signal) with a root mean square (rms) amplitude dependent on the BER signal supplied by the error corrector 30.

The output of the error corrector 30 is supplied to a decoder and digital–to–analogue converter 100 which converts the error–corrector–processed data into an analogue output signal. The analogue output signal is then divided into a "clean" (not–degraded) output signal 110, and a degraded output signal 120 which represents the output of the decoder/DAC added (by an adder 130) to the analogue noise signal

from the noise generator 90.

This arrangement avoids the need for an enable signal to control the noise generator 90, since both "clean" and degraded outputs are generated by the apparatus and the user can select the appropriate output depending on whether he wishes to monitor the error rate.

Figure 3 is a schematic diagram of a further embodiment, in which the error corrector 30' generates two BER values for video and audio data respectively. These are supplied to a two-channel noise generator 140 which, under the control of an enable signal 80, generates video noise 142 and audio noise 144 as separate noise outputs. The rms amplitudes of the video noise 142 and the audio noise 144 outputs depend on the corresponding level of the BER for video data and audio data respectively.

The error-corrector-processed output of the error corrector 30' is transformed to respective video and audio analogue output signals by a decoder/DAC 150. The video output signal is then added to the video noise 142 by an adder 160, and the audio output is added to the audio noise 144 by an adder 170. This allows the user to receive an indication of the quantity of data errors in the video and audio replayed data respectively.

Figures 4 and 5 are schematic graphs illustrating the relationship between the amount of signal degradation generated by the error generator 40, the noise generator 90 or the two-channel noise generator 140 against values of the BER signal from the error corrector 30 (30').

In Figures 4 and 5, the solid line illustrates the effect of uncorrectable errors on degradation of the output signal. Thus, below a threshold BER_{THR}, the error corrector can fully correct data errors in the replayed data, and so these errors have no effect on the error-corrector-processed data. Above the BER value BER_{THR}, the error corrector can no longer fully correct data errors and there is a dramatic and sudden effect on the degradation of the output signal of the error corrector.

The two broken lines in each graph represent examples of possible response characteristics of the error generator 40, the noise generator 90 or each channel of the two-channel noise generator 140. In order to show these on the same graphs, the vertical axes of Figures 4 and 5 represent a schematic measure of "applied signal

degradation", irrespective of whether that degradation is achieved by inserting digital or analogue noise. For example, however, the "applied signal degradation" could represent the rms amplitude of an inserted analogue white noise signal, or the error rate in bit-errors per second of an inserted digital noise signal.

In particular, therefore, two curves 200, 210 represent a steady, proportional, increase in the applied signal degradation with the BER value. The curve 200 continues to increase even when the value BER_{THR} has been exceeded, although typically the effect of the inserted degradation would then be swamped by the collapse of the error correction system. Thus, in another case, the curve 210 represents a steady proportional increase in the applied signal degradation until the value BER_{THR} is reached, at which point no further signal degradation is applied by the error generator 40 or the noise generator 90.

In another embodiment, however, it is recognised that there is no need to draw the user's attention to trivially small error rates, so the applied signal degradation for curves 220, 230 is zero until the BER value reaches a lower threshold value BER(0). For BER values of BER(0) upwards, the applied signal degradation increases linearly. In the case of the curve 220, this linear increase continues even when BER_{THR} is reached, but for the curve 230 signal degradation is no longer applied when BER_{THR} is reached.

CLAIMS

1. Data receiving apparatus for receiving an input digital signal comprising an input signal data stream and associated error correction data, the apparatus comprising:

an error detector for detecting a quantity of data errors in the input signal data stream;

an error corrector for correcting data errors in the input signal data stream using the associated error correction data, to generate an error–corrector–processed signal data stream; and

signal degrading means for degrading a signal derived from the error–corrector–processed signal data stream by an amount dependent on the detected quantity of data errors in the input signal data stream.

2. Apparatus according to claim 1, in which the signal degrading means is operable to add data errors to the error–corrector–processed signal data stream.

3. Apparatus according to claim 1, comprising a digital to analogue converter for converting data derived from the error–corrector–processed signal data stream into an analogue output signal, and in which the signal degrading means is operable to add an analogue noise signal to the analogue output signal.

4. Apparatus according to any one of the preceding claims, in which the signal degrading means is operable:

(i) not to apply any signal degradation when the detected quantity of errors in the input signal data stream is below a first threshold value; and

(ii) for a detected quantity of errors in the input signal data stream greater than the first threshold value but less than a second threshold value, to apply an amount of signal degradation substantially in proportion to the detected quantity of errors minus the first threshold value.

5. Apparatus according to claim 4, in which the second threshold value corresponds to the smallest quantity of errors at which the error corrector is incapable

of fully correcting using the associated error correction data.

6. Apparatus according to claim 5, in which the signal degrading means is operable:

(iii) not to apply any signal degradation when the detected quantity of errors in the input signal data stream is above the second threshold value.

7. Digital recording/reproducing apparatus comprising apparatus according to any one of the preceding claims.

8. A method of processing an input digital signal comprising an input signal data stream and associated error correction data, the method comprising the steps of÷

detecting a quantity of data errors in the input signal data stream;

correcting data errors in the input signal data stream using the associated error correction data, to generate an error-corrector-processed signal data stream; and

degrading a signal derived from the error-corrector-processed signal data stream by an amount dependent on the detected quantity of data errors in the input signal data stream.

9. Data receiving apparatus substantially as hereinbefore described with reference to Figures 1, 2, 3, 4 and/or 5 of the accompanying drawings.

10. Digital recording/reproducing apparatus substantially as hereinbefore described with reference to Figures 1, 2, 3, 4 and/or 5 of the accompanying drawings.

11. A method of data processing, the method being substantially as hereinbefore described with reference to Figures 1, 2, 3, 4 and/or 5 of the accompanying drawings.

The Patent Office

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Application No:	GB 9604744.4	**Examiner:**	Mr B J Spear
Claims searched:	1-11	**Date of search:**	15 May 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4P (PEF, PEM, PEP)

Int Cl (Ed.6): H04L 1/00

Other: Online: WPI, Inspec

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	Research Disclosures RD375062 dated 20/6/95. WPI Acc. No. N95-268225/35.	1,2,4,5,7, 8

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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